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ABSTRACT

This bulletin sets forth the 65 recommendations of the Commission on Professional Standards and Practices of the National Science Teachers Association "on the kinds and quality of facilities needed for good science learning and teaching, on the conditions of instruction necessary to promote good teaching, and on the provisions that a school should make for the continuous professional growth of its science staff." Recommendations for science facilities include those related to rooms, learning materials, programs, and teachers. In considering the "conditions of instruction" recommendations are made concerning teaching assignments, working space, services for the teacher, and the budget. Within the area of professional growth, recommendations are made about the professional library, learning opportunities, and recognition and incentive. (PR)

RECOMMENDATIONS OF THE COMMISSION ON PROFESSIONAL STANDARDS AND PRACTICES OF THE NATIONAL SCIENCE TEACHERS ASSOCIATION

Conditions for Good Science Teaching in Secondary Schools

Contents

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Introduction

Science teaching, like all teaching, is today rather more art than science. We know too little yet to have much of a science of instruction: too little about how people think and learn; about how they are motivated and how their potential for creativity can be tapped; about human interactions; about the effects of attitudes and social forces on learning: about how to measure quantities that we cannot yet even define well; about a hundred other things that one day we must come to understand. And more than just our insufficiency of knowledge—knowledge cannot, after all, ever be complete and absolute—we lack another essential ingredient of a science of science teaching, namely, fine-grained, pervasive, tested theories of teaching and learning. Such theories are necessary to give the kind of scope and precision that is now missing from teaching and to insure continuing progress.

But this is not to say that we are helpless and at the mercy of our intuitions and biases. If science teaching is an art, it is a refined art, for it is based on decades of experience and on conclusions drawn from critical assessments of that experience. We do, in fact, know some important things about science teaching. This knowledge is mostly qualitative, essentially probabilistic, and often negative; but it is sufficient to suggest the conditions, circumstances, and research that will lead us to better science instruction. The following two examples indicate something of the nature and limitations of our knowledge about science teaching:

1. We can confidently claim that, other things being equal. high school chemistry teachers with college majors in chemistry will be more effective than teachers having only a single course in college chemistry. But since other things very rarely are equal, we cannot be *certain* that of two actual chemistry teachers, the one with the major will be better than the one without. Nor can we say, even for the whole population of chemistry teachers, that 20 units, say, of preparation in chemistry is twice (or any other specific number of times) as good as 10 units, or that 18 units is without exception better than 15.

2. We know that *without* adequate laboratory facilities and materials most students cannot learn biology in any meaningful way. On the other hand, we cannot be sure that *with* such facilities and materials meaningful learning will necessarily take place.

And thus, while it is not possible to specify with total confidence how to insure good science teaching, we know with reasonable certainty that certain factors generally contribute to effective science teaching and that others usually impede such teaching. The National Science Teachers Association, feeling that the time had come to delineate these factors, in 1968 established the Commission on Professional Standards and Practices.[1] The Commission was instructed to study carefully all aspects of the problem, to consult widely, and then to prepare a statement that could serve as a guide to science teachers and school administrators wishing to provide their students with good science instruction.

Broadly speaking, good science teaching requires two things: good teachers and good teaching situations. Neither alone is sufficient. The Commission found it convenient to report its conclusions on these two categories in separate documents. One of these, the *Annual Self-*

1 The Commission members were:
James Rutherford, Harvard University, Chairman
Leonard Blessing, Millburn High School, Millburn. New Jersey
Alfred J. Naish, Buffalo Public Schools, Buffalo, New York
Lois Perry, San Diego Public Schools, San Diego, California
Victor M. Showalter, Educational Research Council of America, Cleveland, Ohio
John W. Shrum, The University of Georgia, Athens, Georgia
Bertram Siegel, Educational Directions, Inc., Westport, Connecticut

Inventory for Science Teachers (ASIST)[2], delineates the characteristics of the truly professional science teacher. The self-inventory format was chosen so that it might directly help junior and senior high school teachers systematically and periodically judge whether or not they meet reasonable professional standards. The other Commission findings are presented in this document on *Conditions for Good Science Teaching in Secondary Schools*.[3] Thus, in ASIST the Commission puts forward the recommendations concerning science teachers, their preparation, and performance standards, and in *Conditions for Good Science Teaching in Secondary Schools* it offers its recommendations concerning schools and what standards they should maintain.

The following pages set forth recommendations on the kinds and quality of facilities needed for good science learning and teaching, on the conditions of instruction necessary to promote good teaching, and on the provisions that a school should make for the continuous professional growth of its science staff. After careful consideration at every level, including review by its full Board of Directors, the National Science Teachers Association on July 18, 1970, adopted these recommendations. Therefore they stand, along with ASIST, as official NSTA Standards.

As knowledge grows, as comprehensive theories of learning and teaching emerge, as our notions of what constitutes good teaching become more sophisticated and demanding, it will be necessary to modify the recommendations in this document. For that reason, the National Science Teachers Association has already inaugurated steps to review and update *Conditions for Good Science Teaching in Secondary Schools* as often as progress warrants.

James Rutherford
Chairman, Commission on Professional Standards and Practices
June 1970

2 Published in the December 1970 issue of *The Science Teacher*. Reprints may be obtained from the National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington, D.C. 20036.

3 The Commission especially acknowledges its indebtedness to the Connecticut Science Teachers Association and to the Science Teachers Association of New York. For their statements on standards see: "Recommendations on Working Conditions for Science Teachers," 1965, available from the Connecticut Science Teachers Association, Professional Standards Committee, Box 226, Norwalk, Connecticut; and "STANYS Outlines Good Working Conditions." *The Science Teacher*, October 1968.

Resources for Learning

From the standpoint of students, it is reasonable to look upon schools as institutions that provide resources for learning. In this sense "resources" refers to all things and means that aid or facilitate learning and to the entire atmosphere for learning. Thought of in this way, learning resources must include people and programs no less than buildings and books. A high school that has magnificent science laboratories but poorly trained science teachers—or vice versa—cannot claim to have adequate science learning resources. Nor can a school be satisfactory that lacks the kinds of science courses necessary to serve all students, no matter how good the laboratories, how up-to-date the texts, how complete the library, how competent the science teachers.

Thus, in any high school, resources for learning should include:

- Suitable rooms for studying science
- Sufficient science learning materials
- A modern and comprehensive program of science instruction
- Competent science teachers

SCIENCE ROOMS

Certainly there is some element of truth in the romantic notion that learning can take place anywhere and under any circumstances. But the larger truth is that the systematic, effective learning of science by large numbers of students requires the provision of rooms and spaces carefully designed for that purpose. These learning spaces and their furnishings must take into account: (a) the great diversity of students who will use them, (b) the nature of science, (c) current approaches to and trends in science teaching, and (d) the need always to keep the safety of students foremost in mind. The consequence will be a set of well-furnished and safe science rooms that include spaces for laboratory work, for group instruction, and for individual study.

Laboratories

The time is surely past when science teachers must plead the case for school laboratories. It is now widely recognized that science is a process and an activity fully as much as it is an organized body of knowledge and that, therefore, it cannot be learned in any deep and meaningful way by reading and discussion alone. The recommendations that follow are offered as an aid in assessing or designing science laboratories for student experimentation.

1. There should be at least one separate laboratory for each kind of science course offered.

> *This recommendation applies to interdisciplinary science courses—general science, earth science, life science, etc.—no less than to the basic sciences of biology, chemistry, and physics. Furthermore, it is intended to apply to all science courses, irrespective of whether or not they are labeled "college preparatory." Experimentation is central to all science, and the argument for providing school laboratory facilities is based on that fact, a fact totally unrelated, of course, to the vocational plans of the students.*
> *Short term economic advantage may make it attractive for a school administrator to insist that one room, say, a chemistry laboratory, be used also for the teaching of other courses, perhaps physics or mathematics. But considerations of effective teaching, of safety, and even of long range economics suggest otherwise. The reasons are well known to science teachers. One is that many worthwhile experiments simply cannot be completed in one class period. Thus it is important to be able to set up apparatus in a laboratory and leave it out for extended periods of time; but it is neither safe nor wise to do so if another subject is to be taught*

in the laboratory the next period, or if the laboratory is to be used by another group of students. Another reason is that a teacher needs access to his laboratory at times during the day when he is not teaching; but if other courses are programmed into a given laboratory, then that space is unavailable to him during the school day. A teacher needs this time in his laboratory, not only to prepare for instruction, but also to give him the scope and time and motivation to turn the room into an attractive place for learning, a place in which the whole atmosphere promotes a desire for learning. And, of course, a laboratory designed to accommodate one science is a special room—in the same sense as an art room, a language laboratory, or a gymnasium—and as such is not suitable for teaching other courses, usually not even other sciences.

This recommendation should not be interpreted to oppose combination classroom-laboratory rooms. Such rooms can be effective at any grade level, and it is possible to design them at reasonable costs and still meet the intent of Recommendations 3 to 13 below.

2. There must be enough laboratory rooms provided for each science course to accommodate all students who can profit from the course and wish to take it.

The prospect of having to build a second or third biology laboratory, for instance, should not be avoided by reducing the biology laboratory time below a reasonable standard (a minimum of about 40 percent of the total instructional time), by overscheduling one laboratory (no school laboratory should have classes programmed into it more than 80 percent of the total school instructional time) or by artificially restricting enrollments.

3. Each laboratory must be large enough to accommodate real experimentation.

How much space this is depends upon such variables as the nature of the course, whether or not the laboratory is used also for classroom discussion, and how much the science program emphasizes individualized instruction. A reasonable rule of thumb to cover most situations is that there be a minimum of 45 square feet (5.5 square meters) of space per student if the room is a combination classroom-laboratory, and a minimum of 35 square feet (4 square meters) per student if the space is strictly for laboratory. However, it should be kept in mind, for reasons cited elsewhere, that no matter how large an existing laboratory may be, no more than 24 students should be assigned to it at any one time; and all new laboratories should be designed to accommodate 24 or fewer students.

4. Each laboratory should have ceilings that are at least 10 feet (3 meters) high.

This is necessary because of the nature of many experiments and demonstrations and because volume is important in mitigating the effects of odors, heat, and noise that are inevitably generated in laboratories. It is also necessary in order to be able to hang charts and displays where they can be seen by all students.

5. Each laboratory should be appropriately furnished for each science.

This will be different for the different science courses, but in every case there must be ample work surface (at least one square meter per student) that is smooth, unobstructed, and level.

6. Every laboratory should have conveniently located electric, gas, and water outlets.

The number and location will depend upon the course for which the laboratory is designed. Master cutoff switches for electricity and gas should also be available.

7. Waste disposal facilities must be provided in all laboratories.

These should include sinks with lead or special plastic piping in each laboratory, non-corrosive waste receptacles in each laboratory, and fume hoods in chemistry laborato-

ries and in any other laboratories where noxious and unpleasant gases may be generated.

8. For reasons of work efficiency and safety, laboratories should have lighting which takes into account the variances in working conditions common to science laboratories.

While 100 foot-candles of diffused light may be adequate for most situations, certain aspects of close work may require more.[4]

9. Reasonable considerations of comfort and health require that each laboratory have the capability of renewing the room air at a rate compatible with normal student occupancy and the potential uses of science laboratories, such as maintenance of etc. animals, release of noxious gases,

10. Fire blankets and fully operable fire extinguishers must be located in each laboratory where they are quickly accessible. Every laboratory should be protected by automatic overhead sprinklers.

11. Chemistry laboratories must contain an emergency shower, an eye-wash fountain, and safety goggles for all students.

12. Every science laboratory must have two unobstructed exits.

These should open into a main passage or to the outside of the building, not into a supply room, office, or other intermediary space. In order to insure quick egress it should not be possible to lock the doors from the inside.

13. There should be an annual, verified safety check of each laboratory.

This can be conducted during the summer by the school's maintenance engineer provided he follows a list of items to be checked that has been approved by the science department chairman. At the beginning of the school year each science teacher should receive written notification that in his laboratory the gas lines and valves, the electrical lines and outlets, the exhaust fans, etc., have been tested and either found safe or repaired. Throughout the school year each science teacher should be alert to the appearance of any safety hazards and should report them immediately to the principal in writing.

[4]Some further specifics may be obtained from the following publication: Lighting for hospitals. *Illuminating Engineering*, June 1966, p. 24.

Classrooms

In the traditional mode of instruction students are brought together in groups of moderate size for purposes of discussion, demonstrations, watching films, and the like. While some of the newer approaches to science teaching put more emphasis on individual student activity, they, too, usually require space for group work. The following recommendations apply to such spaces, whether they are provided as part of enlarged laboratories or as separate rooms.

14. No more than 24 students should be assigned to a space intended for group discussion and activity (as distinct from large-group lecture).

This recommendation should not be taken to discourage experimentation with novel ways of grouping students for instruction, provided it is real experimentation based on educationally defensible premises. It does oppose taking the highly probable chance of undermining effective group teaching for reasons of scheduling convenience or to lower costs.

15. A science classroom should have full audiovisual capability and facilities for conducting scientific demonstrations.

Thus it should be equipped with: a demonstration table having a sink and electrical, gas, and water services; outlets for audiovisual equipment; screens for regular, overhead, and rear-screen projection; provision for darkening; and ample blackboard space (approximately one-half of the circumference of the room).

Individual Study

As a consequence of greater concern for individualized instruction, the trend is strongly toward more and more independent study by students. While there will be a place for group instruction for a long

time to come, perhaps always, it is becoming increasingly clear that many students find greater challenge and actually learn better through independent study than through group instruction, and that, consequently, every school should make some provisions for it. The following recommendations apply to any high school science department, regardless of the particular mix it may currently have of group and individualized instruction.

16. Specialized facilities are needed.

> *These should include at least a greenhouse or plant growth facilities, an animal room, a darkroom, and a science shop. If at all possible, outdoor facilities on the school site should be preserved or restored to natural conditions and utilized for science teaching.*

17. Individual project areas are needed for students working on special experiments.

> *Ample storage for projects in progress (at least 1/3 cubic meter per station) is as necessary as adequate working space.*

18. Ample science library space must be available.

> *This facility, which is in addition to the small working library in each science laboratory, will ordinarily be a designated portion of the school's main library. If it is maintained, in whole or in part, as a separate room within the science department, then professional help must be provided to operate it. In either case, the library must be large enough to accommodate a sizable number of students at one time and be comfortable, well lighted and convenient for serious work. (See Recommendation 23 for guidelines on stocking the science library.)*

19. Conference rooms are needed.

> *Conferences between teachers and students will preferably take place in the teacher's own school office, or in the teacher's laboratory when it is not being used for instruction. If, contrary to the recommendations in this report, each science teacher does not have private office space (see Recommendation 42) and the laboratories are over-scheduled (see Recommendation 2), then it is incumbent upon the school to provide special rooms for student-teacher conferences.*

SCIENCE LEARNING MATERIALS

When one thinks about the great variation in student interests, purposes, abilities, learning styles, and backgrounds, and then on the other hand about the complexity and multiple dimensions of science itself, the need for a wide assortment of diverse science learning materials becomes dramatically evident. The following recommendations are intended to offer some guidance in determining the kind and quantity of such materials.

20. When needed for learning, individual textbooks and laboratory manuals should be available without cost to every student.

> *In many ways textbooks are becoming relatively less important in science teaching. There is increasing agreement that a textbook as such should serve as only one of several sources of information and also that different students need different texts. Still, most students need access, at school and at home, to a resource that will lead them through the conceptual structure of the course and that can serve as a convenient study guide and reference book. Except in courses specifically designed to operate without a textbook and without specified laboratory experiments, at least one textbook and one laboratory manual should be provided to every student.*

21. The science textbooks used by students at any time should be no more than four years past the date of the last major revision.

> *It is the nature of science that while in certain respects it has great stability, it is on the whole dynamic and rapidly advancing. This is even more dramatically true of the applications of science—which are also a concern of science instruction. One*

consequence of this is that textbooks, which are necessarily somewhat dated even before they ever appear in the schools, become obsolete more rapidly than textbooks in other fields. The remedy is to replace science texts as frequently as possible, certainly no less often than every four years, with texts that are up-to-date in content, organization, and spirit.

22. For each science course there should be an ample supply of diverse printed materials to supplement the textbook and laboratory manual.

It is futile to think of any textbook, no matter how good, serving all students equally well. To back up the textbook and laboratory manual, the science department should have readily available—preferably stocked in the classrooms and laboratories of the courses they relate to—such printed materials as: programmed instruction booklets; a wide selection of other textbooks, ranging from extremely easy to more advanced than the one being used; computer programs, if computer facilities are available; and magazines and reprints of articles of special relevance.

23. The school science library should contain an adequate selection of books, periodicals, and pamphlets on the sciences, the applications of science, and the history, philosophy, and sociology of science.

Included should be encyclopedias of science, science dictionaries, handbooks, nonfiction, novels, a large selection of science magazines, and files of pamphlets and documents from government agencies, industry, and scientific societies. These should vary in reading difficulty, mathematical sophistication, and level of abstraction so as to include works in every topic or category ranging from junior high school level up to college level. The chief guidance in selecting materials for the science library should come from the science teachers and science department head. Valuable suggestions can be found in the book review sections of The Science Teacher *and* Science and Children, *in other professional journals, and in the* AAAS Quarterly Review of Science Books *and other publications of the American Association for the Advancement of Science (1515 Massachusetts Avenue, N.W., Washington, D.C. 20005).*

24. An adequate supply of modern science equipment should be available for individual and small group activities and experiments, in quantities sufficient to execute the locally adopted curriculum.

A school laboratory is essentially of no value unless there exist the instruments and materials necessary for carrying out experiments. The kinds and quantities of equipment needed cannot be specified without knowledge of the particular courses taught and of the relative emphasis placed upon group instruction and on individual experimentation. If any of the new, nationally developed, science courses are being taught, the school should obtain at least the minimum quantities specified by each of those groups.

25. A diverse supply of audiovisual learning materials needs to be readily available for each science course.

Those materials used frequently, such as film loops and transparencies, should be regarded as permanent equipment and be located either in the rooms where they will be used or in the adjacent storage area so that they will be readily available to teachers and students. Other materials, such as 16mm sound films, that are used once or twice a year and are relatively more expensive, can be obtained by loan; but in the latter case an adequate rental budget must be provided.

26. Certain items of audiovisual equipment should be provided as permanent equipment of individual courses.

Many modern science teachers use audiovisual equipment frequently, even almost daily. Items of such equipment, such as overhead projectors and film loop projectors, need to be available on the same basis as classroom blackboards, i.e.,

available to be used as needed without excessive "planning ahead" and formal ordering. This becomes all the more important as individualized instruction becomes more common.

SCIENCE PROGRAMS

In a given school the proportion of students who have the opportunity to learn the kind of science that serves their interests and needs, and to learn it in a way that matches their abilities and learning styles. depends upon the total science program offered in the school. If the program is made up of a flexible arrangement of up-to-date courses and of opportunities for independent study, and if it provides ample time for guided learning, then all students will be well served. There is no one best science program, but any good program will meet at least the following recommendations.

27. The program must provide at least two years of science for every student.

This can be accomplished in the context of a relatively few different science courses if each of the courses is flexible enough in design and rich enough in resources to cope with the full range of student diversity; or it may be achieved by offering a large selection of courses that vary significantly from each other in pace, form, level of abstraction, and the like. The need is not to force every student—regardless of the strength of his interest in science, of whether or not he is college bound, or of his academic skill—into the same two years of science, but rather to design a program of science that contains within it the ingredients from which at least two years of significant study can be fashioned for every student.

28. The science program must provide the opportunity for science-oriented students to study science every year.

For some such students it is merely a matter of having enough challenging courses to select from. For other students—for example, those who have become intensely interested in some problem, aspect, or experimental technique of science, or in an interdisciplinary science, or in the history and philosophy of science—opportunities for guided independent study are necessary.

29. There should be at least 315 minutes per week of instruction available to every student enrolled in a science course.

This much time is needed to provide for laboratory work, discussion, group work, independent study, evaluation, and consultation. While this is more time than most non-science courses in high school traditionally claim, the need for extensive laboratory work in all science courses is the main reason for allotting extra time.

30. All science courses must include student laboratory work.

The purpose of any science course is to help students learn science—real science as it actually is. Experimentation is such a fundamental component of any of the natural sciences that "understanding science" depends upon understanding, among other things, how experimentation is conducted, how it is related to the other components of the scientific endeavor, and what its powers and limitations are. This can be gained only by doing; reading about experimentation and inquiry is not enough. Thus the need to make all science courses—general science no less than physics—laboratory courses in the fullest sense is rooted in the nature of science itself, and is unrelated to the title or clientele of the courses.

31. The science program should be under constant review.

The science department must have some formal, systematic, and continuous plan for evaluating its individual courses and the science program as a whole. This does not mean that every course must receive a full scale examination every year but that the science department have a planned cycle of critical study. With-

in a period of no more than four to five years, each course, the relationships between the courses, the non-course study opportunities, and the appropriateness of the science program for all students should receive intensive department attention. On that basis judgments can be made and changes instituted as necessary. Only in this way can there be any confidence in the strength of a school's science program. For science, the methods for teaching science, and the needs of students are all changing so rapidly that it is unlikely that today's programs, however sound, will remain appropriate for long.

A corollary of this recommendation is that the science department has an obligation to examine with great care the new science courses developed by the national curriculum groups. These courses were designed and tested over a period of years by large teams of science teachers, scientists, science educators, learning psychologists, and specialists of many kinds. This does not insure that each of the new courses is appropriate for use in every school, but it does suggest that they cannot in good conscience be rejected out of hand. In order for a fair examination of any one of these new courses to be made, it is important for at least one teacher in the department to attend a summer or in-service institute dealing with that course. Some number of stipends are usually available from the National Science Foundation, but, in lieu of such support, the school itself should underwrite the teacher's expenses.

SCIENCE TEACHERS

Without guidance from knowledgeable, well-trained science teachers, students can gain very little from buildings and books and apparatus, however modern and plentiful. Since the science teachers constitute the single most important science learning resource that the school has to offer its students, very careful attention should be given to the process of their selection. To that end, the following recommendations are made.

32. Every teacher in the science department should meet the standards of preparation and performance outlined in the NSTA Annual Self-Inventory for Science Teachers (ASIST).

In case any permanent teacher does not meet some of the recommended standards, he should be given help by the school in remedying those deficiencies within a reasonable period. In hiring new science teachers, an agreement to remove specified deficiencies in a designated time should be a condition of employment, and permanent status should depend upon the agreement's being honored. And, every bit as important, teachers should be sought who, in addition to sound preparation, have a contagious enthusiasm for their work and for young people.

33. The number of teachers in a science department should be large enough and the distribution of their science fields should be wide enough to support a full science program.

In a large school this is easily accomplished. In a small one it can be attained by seeking individual teachers with substantial backgrounds in several fields or with preparation in a broad area of study, as, for example, physical science. However, even the smallest high school should have at least two science teachers, for it is unreasonable to expect any one person to be competent in the biological, physical, and earth sciences.

Conditions of Instruction

By conditions of instruction are meant the circumstances under which teachers work. Perhaps the most important of these conditions is the general vigor and health of the learning environment. If there is mutual respect between teachers and students and administrators, if there is a general high regard for learning for its own sake, and if the educational interests of all students are kept paramount, then it is likely that good conditions for learning and teaching will prevail.

The recommendations that follow deal with some of the specifiable aspects of conditions for instructuon. They are based on the assumptions that a science teacher's total assignment must reflect the complexities of his job, that he must be given ample time both for instruction itself and for preparation, and that he needs to be provided with ample backup support, such as suitable working spaces, an adequate operating budget, and services of several kinds.

TEACHING ASSIGNMENTS

34. Science teachers should not be asked to be responsible for the education of students in content areas in which they are not competent in subject matter.

> *This recommendation should not preclude involvement in developing or teaching interdisciplinary courses, experimentation in new modes of presentation, team teaching, interdepartmental seminars, or other as yet unforeseen innovations.*

35. A science teacher should not have more than two preparations or class-management situations.

> *Because of recent changes in the organization of science instruction, it is no longer as clear as it once was what constitutes a "preparation." In a sense every single class constitutes a separate preparation. Indeed, as schools move toward individualized instruction, the teacher's job is changing radically, requiring him to think in terms of guiding each of his students as a separate person and diminishing his concern for group instruction. But whether a teacher operates predominantly in the group instruction mode or relies mainly on individualized instruction, there needs to be some reasonable limitation to his separate preparation situations.*

36. If a science teacher is given assignments of unusual responsibility, his total load should be adjusted to a reasonable level.

> *A teacher given an assignment such as department chairman, master teacher, supervisor of apprentice teachers, or chairman of a curriculum study group, cannot be expected to carry it out effectively and still do full justice to his primary responsibility of teaching unless some adjustment is made. Of course, the adjustment should be in proportion to the magnitude and intensity of the added assignment.*

37. Each science teacher's week should be programmed so that he has some time available to meet with individual students.

> *Office hours should be posted so that students can consult teachers without difficulty.*

38. All laboratory sections should be strictly limited to a maximum of 24 students per instructor.

> *This restriction is necessary because useful laboratory work—the heart of modern science instruction—requires individual participation by students and close student-teacher liaison. To increase the number above that recommended is to jeop-*

ardize the educational value of science experimentation and inquiry. Furthermore, a teacher simply cannot supervise more than 24 students, even in the restricted sense of keeping order. The risk to student safety and to expensive equipment escalates rapidly as the number of students in the laboratory at one time increases. In instances where the existing laboratories have fewer than 24 work stations, the number of students assigned should not exceed the number of stations.

39. Group discussion classes should be limited to a maximum of 24 students.

Unlike in the laboratory situation, it is not hazardous to students and equipment to have more than 24 students per class, but it is educationally unsound to do so. Classroom discussion and activities (instruction in science, even outside the laboratory, involves more than "talk," if it is not to become disguised lecturing) must provoke the participation of all students and not just the most articulate few. This is difficult to achieve under any circumstances, but as the numbers rise it becomes impossible, and quality of instruction suffers.

40. A science teacher's involvement in extracurricular activities should be limited.

All teachers, including science teachers, must join in the responsibility for carrying out the whole school program (providing, of course, that they have had a hand in designing that program), and certainly this involves more than formal instruction. However, activities not directly related to the science program, like all activities, require time and energy, and thus extensive participation in them may seriously detract from the teacher's ability to fulfill his major teaching responsibilities. Any major non-teaching related assignments accepted by a science teacher should be compensated for by a reduction in his teaching load (see Recommendation 36). If science teachers are not provided with laboratory assistants (see Recommendation 46), then in view of the science teacher's heavy laboratory responsibilities, he should not be asked to take any extracurricular assignments.

WORKING SPACE

The most obvious and uncontested claim for space in a school is for instructional rooms (see Recommendations 1, 2, and 14 to 19). Those are the spaces in which teachers and students work together. However, such facilities are not by themselves sufficient. If the teacher is to make effective use of his instructional time, then he must have available places where he can do the work necessary to prepare for instruction.

41. Ample space is needed for the storage of supplies and equipment.

This space, equivalent to at least 15 percent of the laboratory space, should be adjacent to the laboratories if at all possible. This is in addition to the storage space provided in each laboratory. Some of the newer classroom buildings have been designed so that the storage space is more or less common to all of the laboratories. Such an arrangement may be satisfactory, provided there is continuous adult management of it and provided also that there is separate, isolated storage for flammable, poisonous, and corrosive substances. If animals are kept permanently at the school, then a special animal room must be provided and some arrangement made for year-round humane care of the animals.

42. Every science teacher requires access to a preparation area free from students.

Teachers need a place where they can prepare materials for student experimental work, set up and test demonstrations, and sometimes conduct experiments of their own. Depending upon the design of the science department, these teacher preparation areas may be provided as part of extended storage space or as separate rooms. In either case, the preparation areas must be provided with convenient electric, water, and

gas outlets, waste disposal facilities, and safety devices.

43. Every science teacher should have private office space.

If a teacher has the same classroom all day, and no other teacher uses that room throughout the day, then it may be possible for a teacher to use his classroom as an office. However, those conditions do not prevail in most schools, and since teachers need a place where they can meet their students individually, where they can do their paper work without interruption, and where they can keep files of confidential materials, it is sounder to provide regular office space.

44. The science teacher needs access to a professional library.

This library should exist as a separate facility within the school. Science teachers, faced with the task of staying up-to-date in science and its applications, in the teaching of science, and in matters relating science to society, carry a heavy academic burden. Consequently, they need to study appropriate books and journals almost continuously. To accomplish this, they should have immediate access—this is part of their daily work, not something that can be put off until summers—to a professional library that contains appropriate material. They cannot function effectively for long without such a resource any more than can scientists or college science teachers. (See Recommendations 53-56 for more details.)

SERVICES

In order to do his job well, a science teacher needs considerable assistance of many kinds. No matter how talented a teacher may be in the art of instruction, it does not follow that he is particularly competent at typing, filing, cleaning and repairing equipment, and the hundreds of other chores associated with his job. Furthermore, it is poor economics, as well as shortsighted employment policy, to expect teachers to do ineffectually what others can do better and at lower cost. But it is not only with "chores" that the science teacher needs help. He can do a better job of teaching if he receives leadership and help from someone who is not only himself a master teacher but also someone with extensive knowledge of and deep insight into the major facets of science instruction and curriculum. The following recommendations indicate the kinds of persons needed to provide teacher backup services.

45. Schools employing four or more science teachers should have a science department headed by a chairman.

The prime function of a department chairman—who should meet the standards of preparation and experience set by the National Science Supervisors Association—is the improvement of science instruction. This involves management duties, supervisory functions, curriculum leadership, and seeing that the teachers in the department are given as much help as possible. The science chairman's teaching load should be adjusted to permit him to devote not less than half of each school day to his department duties.

46. Laboratory assistants should be available on a professional basis.

The chief tasks of these paid adult assistants would be to assist the teacher with such things as setting up demonstrations and student laboratory experiments, and ordering, assembling, maintaining, and keeping an inventory of supplies and equipment.

47. Professional secretarial and clerical help should be available to science teachers on a systematic basis.

Such help should be available at least one hour a day to each teacher at a time convenient to him. Student help is no substitute for this.

48. Consultants and specialists should be called in to help the science department and science teachers as needed.

These may be safety engineers, specialists on new science programs, specialists on the utilization of new

learning technology, science educators to help individual teachers with classroom problems, and the like.

BUDGET

Each science teacher must be supported directly or indirectly by an adequate budget. Because of differences in local facilities and programs, it is not possible to specify here the exact size of the budget necessary to meet the annual and long-term needs of all high school science departments; thus it becomes imperative that the budget be arrived at during meaningful consultation with those who understand best the local school science situation, namely, the science teachers themselves. The following recommendations provide some guidelines in the development of an adequate budget.

49. The science department budget should appear as a separate account within the whole school budget, and it should be subdivided functionally.

Separate line items should indicate the amounts budgeted for the purchase of laboratory equipment, for the repair and maintenance of equipment, and for supplies. The intended purpose of this is to eliminate unnecessary confusions over the true size of the science budget, or over the relative distribution within the department between capital outlay and annual operating expenses. Such information is necessary if the science teachers are to plan intelligently.

50. Supplies should be budgeted on a per capita basis with the amount varying according to the nature of the course and the consumable materials involved.

It must also be kept in mind, however, that there exists a bare cost below which any science course cannot operate, no matter how few students are enrolled in it.

51. Budgetary provision needs to be made so that items may be ordered during the school year for new projects, for perishable materials, and for unforeseen contingencies.

To facilitate this, the science department should have a substantial petty cash fund that every teacher in the department can draw upon for purchases of emergency science materials.

52. If a science department does not possess all of the major equipment that the science teachers and department head agree is essential to the department program, then there should be explicit budgetary provision for obtaining all such equipment in no less than three years.

Needless to say, this must be accomplished without unnecessarily reducing the annual operating budget. This recommendation recognizes the fact that major equipment deficiencies usually cannot be made up in a year. A period of three years allows the situation to be rectified in an orderly and manageable way. Decisions on the particular capital items to be purchased and on the order of priorities must be decided by the science teachers, not by school administrators.

Professional Growth

Science teaching is such a complex, dynamic profession that it is difficult enough just for a teacher to stay up-to-date. For him to grow professionally and become better at his work takes a special, continuous effort. During the first few years of his career, a science teacher needs special help and consideration, and then for as long as he continues to teach he must be given every opportunity to increase his knowledge and improve his skills. Only thus can he avoid intellectual and professional stagnation. To help teachers follow a continuous program of professional growth, the school should provide science teachers with a strong professional library, support a variety of learning opportunities, and establish special incentives to encourage self-improvement.

PROFESSIONAL LIBRARY

As indicated earlier, a science teacher needs access to a professional library simply in order to do his day-to-day work. Beyond that, he needs such a resource in order to move ahead in understanding of his job and skill in its performance. While the school's professional library will contain books, journals, and other materials of general educational interest to serve all of the teachers in the school, it should have items of special interest to science teachers. The following are strongly recommended:

53. The school professional library should contain a large selection of books on science education, science, and the history and philosophy of science as recommended by the science teachers.

> *These will generally be more advanced than the books on the same topics in the school's general or science department libraries. Some duplicction of titles may be necessary, however, so that the teachers will not have to preempt books that students may need.*

54. Subscriptions to at least eight science education journals should be maintained by the school professional library. These ought to include, among others, *The Science Teacher, School Science and Mathematics,* and *Journal of Research in Science Teaching,* and journals in various science teaching fields, such as *The American Biology Teacher, Chemistry, The Geology Teacher,* and *The Physics Teacher.*

55. An up-to-date file of science curriculum information and science education research reports should be maintained.

> *Included should be pertinent newsletters, pamphlets, and reports from the national science curriculum development projects, the university Research and Development Centers, the USOE Regional Laboratories, the federal and state education agencies, the National Science Teachers Association, and the various scientific societies.*

56. The professional library should contain one or more microfilm/microfiche readers and draw heavily on the output of the Educational Resources Information Center (ERIC).

> *Most important educational journals are now on microfilm, making it relatively inexpensive for a school to have available a substantial holding of back issues of science education journals even if subscriptions to those journals have only recently been established. In addition, hundreds of valuable reports and documents have now become available on microfiche from ERIC at extremely low cost. Along with a growing file of ERIC microfiche, the library should subscribe to the two main ERIC guides,* Research in Education *and* Current Index to Journals in Education, *both of which are useful to practicing teachers as well as to educational researchers and refer-*

ence *librarians. The* Thesaurus of ERIC Descriptors *should also be on hand.*

LEARNING OPPORTUNITIES

A science teacher cannot grow in mastery of his job merely by reading. From books and journals he can increase his knowledge of science and education and become aware of current trends. However, to succeed in substantially deepening his knowledge, to be able to rethink and reorganize his whole approach to teaching, or to gain skill in applying new ideas and approaches, he must have access to academic resources and opportunities beyond those available in his own school. School policy should encourage teachers to seek out such resources and opportunities by providing incentives, giving help, and rewarding achievement. The recommendations below indicate some ways of doing this.

57. Schools should provide opportunities for the inservice education of science teachers throughout their teaching career.

The teachers should have a voice in determining the content and structure of the in-service program. Released time should be available for the program, and the cost should be underwritten by the school as part of its regular operating budget. In return the school should require the teachers to participate in the in-service program periodically or in some equivalent self-improvement activity, such as summer school or special workshops.

58. Paid sabbatical leaves should be provided for the periodic updating of science teachers.

No less often than every seventh year the teachers should be entitled to a minimum of a half-year leave at full pay or a full year leave at half pay. This pay should not be reduced for teachers who secure a foundation or government grant during the period of their leave.

59. A permanent teacher should be permitted to take leaves-of-absence of up to two years for purposes of further education without jeopardy to his position or salary advances.

60. Science teachers should be allowed a reasonable number of days each year away from school for professional purposes.

These days should be equitably distributed among the science teachers in the department and average at least one day per teacher per year. They should be used for visits to other schools, to colleges and universities, to research centers, to industry, etc., in order to help the teacher keep abreast of current development in science and science teaching. Reciprocal visits should be encouraged with science teachers from other schools.

61. Support should be given so that all science teachers can attend and participate in local, state, and national science teacher conventions.

Time and at least some reimbursement for travel, room and board, registration fees, and other expenses should be provided to teachers on a rotating basis. The school should make it possible for every science teacher to attend his national convention at least once every four years, and state and local ones oftener. Special consideration, in terms of reasonable time off from school without loss of salary, should be given to teachers who hold a major office in a state or national science teachers professional association.

62. Science teachers should be urged to attend National Science Foundation teacher institutes dealing with the new science curricula.

The large-scale science curriculum development projects have designed not only whole new courses but also interesting and forward-looking new approaches to science teaching and a large variety of new learning materials of all kinds. Thus, it is worthwhile to a school, as well as to the teachers themselves, to have teachers attend institutes dealing with these new courses, whether or not the courses are actually used in the school. The National Science Foundation itself provides a certain number of stipends for teachers; how-

ever, the school itself should underwrite the teacher's expenses if necessary.

63. First and second year teachers should be given special consideration.

The first year or two of teaching are likely to be intellectually and emotionally taxing, but they are, nevertheless, especially important years. These are often the years during which a new teacher's attitudes are set, his basic teaching skills learned, and his course for the future fixed. It is crucial, therefore, that the school have special concern for his training and self-improvement. There are several concrete actions that can be taken. One is to set the beginning teacher's instructional and extracurricular load well below that of experienced teachers in the department. At least during his first year as a science teacher, he should have only one academic preparation, and his number of student contact hours should be limited to approximately two-thirds of that of experienced teachers. Second, professional help should be readily available to assist the beginning teacher in dealing with the classroom problems he may encounter. The science department head can function in this capacity, as can the master teachers in the science department. Third, the department head and other experienced science teachers in the department should introduce new teachers to professional association activities and take them to professional meetings of special interest.

RECOGNITION AND INCENTIVE

To expect a science teacher to devote time and energy to self-improvement on top of his regular teaching responsibilities makes sense professionally, but it may not always be realistic. Many teachers are unlikely to undertake or to continue the rigors of such improvement unless they have a strong incentive to do so. Theoretically, the strongest incentive should be the knowledge that further training and study will surely lead to improved teaching. Still, teachers, like other people, eventually become discouraged if extra work on their part seems to bring no reward or acknowledgment. Thus it is important for the school not only to support a strong professional growth program in the ways indicated above but also to provide special incentives and recognition to teachers who do take advantage of opportunities to improve throughout their careers.

64. Teachers who have pursued a program of professional improvement until reaching a superior standard of teaching competence should be rewarded with special recognition.

This might take many forms, but at the very least it should include increased salary, special status as a master teacher, assignment to training and supervision responsibilities, and perhaps a citation as an outstanding professional science educator.

65. Teachers who have attained a special status through advanced study should occasionally be given the opportunity to work on projects of their own choosing.

These projects might include such things as developing new instructional materials, conducting some research on science learning, or developing a new interdisciplinary course with other teachers in the school. Operationally, this opportunity should take the form of adjusting the teacher's instructional load and of providing some financial support if needed.

NATIONAL SCIENCE TEACHERS ASSOCIATION
the professional organization for all teachers of science
1201 Sixteenth Street, N.W., Washington, D.C. 20036